Delphic and Odyssean monetary policy shocks: Evidence from the euro area[⋆]

Philippe Andrade[a,*], Filippo Ferroni[b]

[a] *Federal Reserve Bank of Boston*
[b] *Federal Reserve Bank of Chicago*

Online Appendix
Not for publication

Appendix A. Number of factors and monthly variations in the yield curve

Table A.1 reports the results for testing the number of factors in our datasets. The first two columns report the number of factors need to explain the intraday variations in the OIS forward rates around the monetary policy event in different samples; two factors are needed. The last column singles out the number of factors needed to explain jointly the intraday variations of OIS forward rates and daily variations of ILS spot rates around the monetary policy event; three factors are needed.

Table A.1: The Cragg and Donald (1997) test for the number of factors.

	OIS (1m-2Y)		OIS (1m-2Y) ILS (2Y 5Y 10Y)
Sample	2002-2016	2004-2016	2004-2016
N	9	9	12
$H_0 : k = 1$	40.1 (0.000)	40.1 (0.000)	72.15 (0.000)
$H_0 : k = 2$	30.1 (0.000)	30.1 (0.025)	59.30 (0.000)
$H_0 : k = 3$	21.0 (0.151)	21.0 (0.324)	47.40 (0.005)
$H_0 : k = 4$	-	-	22.83 (0.527)

The table reports the Wald statistics and associated p-values in parenthesis of the Cragg and Donald (1997) test for testing the null hypothesis of $k = k_0$ factors against the alternative that $k > k_0$.

While intraday monetary policy surprises explain a large portion of the volatility in intraday OIS rates, one may wonder how much these surprises contribute to the variation in interest rates at lower frequencies—say, monthly variations. To find out, we run the following regression of the monthly variations in (spot) EONIA swaps at various maturities on Target and Path factors (and a constant, though the results are not shown):

$$\Delta^m OIS = \alpha + \beta \text{Target} + \gamma \text{Path} + \epsilon.$$

Table A.2 presents the results. The Path factor loads significantly in the monthly variation in (spot) EONIA swaps at various maturities. The share of the variance of monthly variations in EONIA swaps explained by the two factors is between 10% and 20% for maturities of one year to three years for the full sample. This share increases as much as about 40% in the second part of the sample. Similar patterns can be found for the average euro-area government bond rates and Euribor interest rates.

[⋆]The views expressed herein are those of the authors and do not indicate concurrence by the Federal Reserve Bank of Boston, the Federal Reserve Bank of Chicago, the principals of the Board of Governors, or the Federal Reserve System.

[*]Corresponding author. Address: 600 Atlantic Ave, Boston, MA 02110 (USA). Phone number: +1 617-973-3847.
Email address: philippe.andrade@bos.frb.org (Philippe Andrade)

Table A.2: Impact of intraday changes in the Path and Target factors on monthly variations in the yield curve

OIS rates	Target	Path	Adj R^2
One month	0.44	0.31	0.01
Three months	0.34	0.48^{**}	0.02
Six months	0.36	0.75^{***}	0.06
One year	0.42	1.17^{***}	0.11
Two years	0.62	1.48^{***}	0.15
Three years	-0.18	1.69^{***}	0.21
Five years	-0.44	1.44^{***}	0.16
Ten years	-1.09^{*}	0.92^{***}	0.07

Regression estimating the monthly variation of EONIA swaps at the different maturities explained by the (intraday) Target and Path factors. One (two, three) star indicates the statistical significance at 1% (5%, 10%) computed with robust standard errors.

Appendix B. 1-day vs 2-day reaction of ILS to HF MP surprises

Table B.3: One day variations

	ILS											
	1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y	12Y	15Y
Target	0.39	-0.38	-0.56*	-0.39	-0.22	-0.08	-0.15	-0.11	-0.13	-0.04	-0.17	-0.11
Path	-0.43	0.15	0.18**	0.11	0.11	0.13**	0.09*	0.12**	0.10	0.11*	0.10*	0.06
R^2	0.07	0.04	0.11	0.06	0.05	0.03	0.02	0.03	0.02	0.03	0.03	0.00
Target	0.43	-0.37	-0.56*	-0.38	-0.20	-0.05	-0.13	-0.09	-0.11	-0.00	-0.14	-0.09
Path	-0.43	0.16	0.20***	0.13	0.13	0.16**	0.11*	0.14**	0.12*	0.13*	0.12**	0.08
R^2	0.07	0.04	0.12	0.06	0.06	0.05	0.04	0.05	0.03	0.05	0.03	0.01
Target	-0.61	-0.32*	-0.15	-0.25	-0.34	-0.36*	-0.35*	-0.30	-0.34*	-0.54**	-0.45**	-0.21
Path	-0.31	-0.28*	-0.42**	-0.39**	-0.37	-0.44*	-0.43**	-0.41*	-0.36*	-0.30	-0.36*	-0.43*
R^2	0.07	0.01	0.09	0.09	0.07	0.16	0.20	0.14	0.12	0.14	0.19	0.16

Regression estimating responses of the revision (one-day) of market-based inflation expectations (spot rates) to Target and Path factors, full sample and subsamples. First rows full sample, second rows pre-ELB and third rows near-ELB.

Table B.4: Two days variations

	ILS											
	1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y	12Y	15Y
Target	0.23	-0.41	-0.53	-0.24	-0.08	0.04	-0.14	-0.06	-0.01	0.12	0.07	0.05
Path	0.43***	0.34***	0.33***	0.19**	0.24***	0.26***	0.18***	0.18***	0.16**	0.17***	0.23***	0.13**
R^2	0.07	0.07	0.12	0.05	0.09	0.11	0.06	0.06	0.05	0.06	0.11	0.04
Target	0.31	-0.37	-0.49	-0.19	-0.02	0.10	-0.08	0.00	0.05	0.18	0.13	0.11
Path	0.48***	0.38***	0.37***	0.23***	0.28***	0.30***	0.22***	0.21***	0.20***	0.20***	0.27***	0.17***
R^2	0.09	0.09	0.14	0.07	0.14	0.18	0.09	0.10	0.09	0.12	0.18	0.09
Target	-0.73	-0.64	-0.64*	-0.62**	-0.73**	-0.78***	-0.86***	-0.84***	-0.72***	-0.83***	-0.66***	-0.58**
Path	-0.83***	-0.64***	-0.76***	-0.83***	-0.69***	-0.73***	-0.68***	-0.63***	-0.65***	-0.63***	-0.70***	-0.81***
R^2	0.29	0.24	0.28	0.29	0.27	0.36	0.39	0.43	0.46	0.51	0.51	0.55

Regression estimating responses of the revision (two-day) of market-based inflation expectations (spot rates) to Target and Path factors, full sample and subsamples. First rows full sample, second rows pre-ELB and third rows near-ELB.

Appendix C. Identification with zero and sign restrictions

Let X be a $T \times k$ matrix containing the OIS and ILS variations used for identification. We assume that the data are generated by the following factor structure:

$$X = F\Lambda' + e,$$

where F is a $T \times 3$ matrix containing the unobserved factors, Λ is a $k \times 3$ matrix of factor loadings, and e is a matrix of i.i.d. normal shocks of appropriate dimensions. We extract factors and loadings using principal component analysis (PCA). We rotate the factor using an orthonormal matrix H (that is $HH' = H'H = I$) so that

$$Z = FH.$$

Substituting the latter equation into the factor model we obtain

$$X = Z(\Lambda H)' + e.$$

Without loss of generality, assume that the ordering of the variables in the X matrix is the following: current-month forward EONIA, one-year ahead forward Euribor-3M, five-year ILS spot rate, and then all the remaining variables. Our identification is achieved assuming that ΛH has the following structure:

$$\Lambda H = \begin{pmatrix} * & 0 & 0 \\ * & + & + \\ * & + & - \\ \vdots & \vdots & \vdots \\ * & * & * \end{pmatrix},$$

where an asterisk indicates a number. Imposing the zero and sign restrictions on ΛH is equivalent to imposing the zero and sign restrictions on $\Lambda_{3:3}H$, which is the top 3×3 submatrix of ΛH. In order to obtain the desired rotation, we proceed in two steps. We first obtain the Cholseky decomposition of $\Lambda_{3:3}\widetilde{H}$, that is,

$$\Lambda_{3:3}\widetilde{H} = \begin{pmatrix} * & 0 & 0 \\ * & * & 0 \\ * & * & * \end{pmatrix}$$

and recover $\widetilde{H}$ by

$$\widetilde{H} = \Lambda_{3:3}^{-1} chol(\Lambda_{3:3}\Lambda_{3:3}'),$$

given that $\Lambda_{3:3}\Lambda_{3:3}' = \Lambda_{3:3}\widetilde{H}\widetilde{H}'\Lambda_{3:3}'$. We then rotate the $\widetilde{H}$ matrix using the Givens rotation such that the structure of ΛH is preserved. More formally,

$$\widetilde{H}Q(\theta) = H,$$

where

$$Q = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{pmatrix}.$$

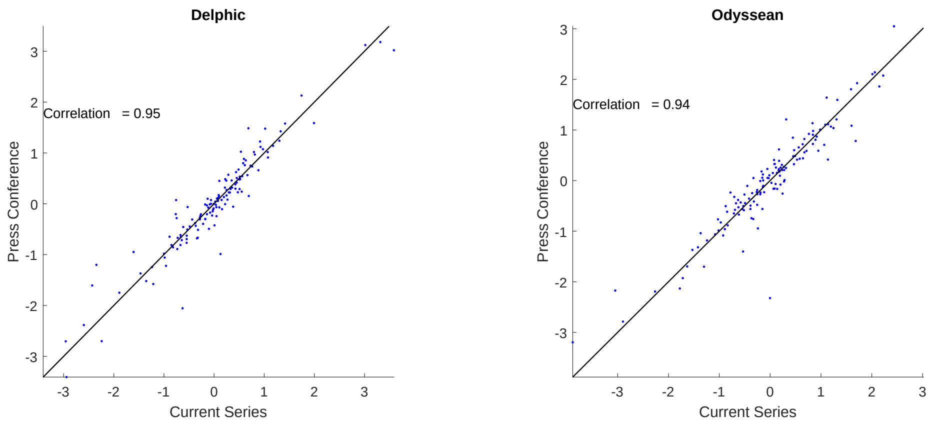
This rotation will leave unchanged the first row and column of $\Lambda_{3:3}\widetilde{H}$, thus preserving the zero restrictions. We consider a grid of values for θ ranging from 0 to π with a 0.05 step. For each of these values we keep the rotation if the signs in $\Lambda\widetilde{H}Q(\theta)$ are satisfied. We then consider the average of the accepted rotations, $H_m = \Lambda_{3:3}^{-1} 1/J \sum_j^J \Lambda_{3:3}\widetilde{H}Q(\theta^{(j)})$.

Appendix D. HF Identification of MP surprises: Robustness

We applied our identification approach to the variations in the future interest rate contracts around the monetary policy press conference and contrasted the resulting series with our original ones which - we recall - are constructed using the full monetary policy event window. Figure D.1 reports the scatter plots and correlations. A quick glance of the plots suggests that most of the information content of the Delphic and Odyssean surprises is revealed during the press conference.

Excluding the press release however does not change the main conclusions of the paper. Table D.5 report the impact of the Delphic and Odyssean (and target) factors constructed using the full monetary policy event and the press conference window respectively on various asset prices. The impact coefficients of Delphic and Odyssean surprises on the real and nominal assets change very little from our benchmark specification. If anything, Delphic surprises have an impact on nominal OIS which is about 20 bps lower relative to benchmark. Moreover, the impact of the Odyssean surprises on inflation expectations is slightly stronger at shorter horizon (one-,two- and three-years out) and weaker at longer maturities relative to the case where we consider the full monetary policy event as our identification window. Figures D.3 and D.4 compare the responses to an impulse in the Odyssean factors using the variations of the interest rates in a narrow window around the monetary policy event (left panels) and press conference (central panels). Transmission dynamics are very similar to the ones obtained considering the full monetary policy event window.

Figure D.1: Scatter plot between the Delphic and Odyssean factors extracted considering the full event window (x-axis) and the analogous factors extracted using only the press conference window (y-axis). Factors have unit variance.



Monetary policy affects horizons that go beyond 2-years (see Table 2). For this reason, it is legitimate to wonder if the maturity selection might have an effect on our identified factors. To verify that our results are not sensitive to the specific maturity selection of the OIS contracts we extend our original maturity structure including the 3-year OIS rate and German bund yields with maturity 5 and 10 years, that we obtained from the public database of Altavilla, Brugnolini, Gürkaynak, Motto and Ragusa (2019). We then computed the implied Delphic and Odyssean factors. Figure D.2 reports the scatter plots and correlations with our original series. A quick glance of the plots suggests that the construction of the Delphic and Odyseean surprises is not sensitive to this specific maturity selection.

Table D.5 reports the response on various asset prices to an increase in the Delphic and Odyssean (and target) factors constructed using the original and extended maturity spectrum. Relative to our benchmark specification, differences are marginal. It is important to highlight that the Odyssean factor constructed using the extended maturity spectrum has a peak effect on the nominal rates at three year horizon; the same peak effect obtained with the original maturity structure. Moreover, the Odyssean factor has no impact on the long end of the yield curve. In other words, these shocks have similar properties than the FG factor identified in Altavilla et al (2019) who also peaks at a maturity to two to three years (see their figure 3). This also explains why limiting the maturity spectrum to 2 years does a good job at identifying these shocks.

Figures D.3 and D.4 compare the responses to an impulse in the Odyssean factors using the variations of the interest rates with different maturities structure. Transmission dynamics are very similar to each others.

Figure D.2: Scatter plot between the Delphic and Odyssean factors extracted considering the full event window (x-axis) and the analogous factors extracted using a maturity spectrum of the yield curve extended to 10 years (y-axis). Factors have unit variance.

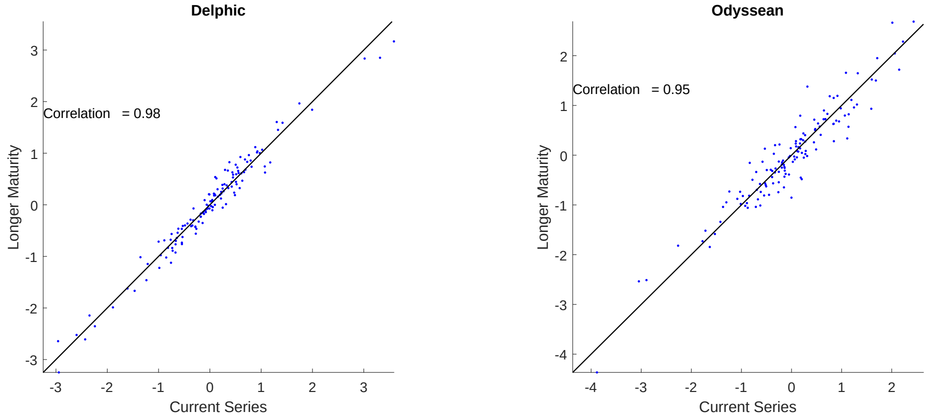


Table D.5: Identification windows and maturity spectrum

	Full Event			Press Conference			Longer Maturities		
	Delphic	Odyss.	Adj R^2	Delphic	Odyss.	Adj R^2	Delphic	Odyss.	Adj R^2
Interest Rates									
OIS 1m	0.10(0.10)	-0.08(0.12)	0.13	0.09(0.09)	0.03(0.12)	0.03	0.09(0.09)	-0.06(0.10)	0.15
OIS 1y	1.22***(0.18)	0.37**(0.21)	0.58	0.99***(0.15)	0.29**(0.21)	0.56	1.12***(0.16)	0.26*(0.19)	0.57
OIS 2y	1.59***(0.16)	0.48**(0.25)	0.59	1.33***(0.15)	0.40**(0.25)	0.53	1.50***(0.14)	0.44**(0.19)	0.60
OIS 3y	1.53***(0.17)	0.50**(0.25)	0.54	1.34***(0.16)	0.45**(0.27)	0.48	1.48***(0.15)	0.54***(0.20)	0.57
OIS 5y	1.40***(0.15)	0.48**(0.28)	0.46	1.21***(0.15)	0.24(0.28)	0.39	1.35***(0.14)	0.44**(0.21)	0.49
OIS 10y	0.88***(0.18)	-0.00(0.36)	0.17	0.76***(0.16)	-0.18(0.30)	0.15	0.91***(0.16)	0.14(0.28)	0.23
Inflation									
ILS 1Y	1.55***(0.17)	-0.35(0.17)	0.46	1.41***(0.16)	-0.49**(0.16)	0.45	1.25***(0.14)	-0.78***(0.17)	0.41
ILS 2Y	1.51***(0.12)	-0.65***(0.11)	0.85	1.33***(0.16)	-0.91***(0.19)	0.75	1.24***(0.11)	-0.93***(0.12)	0.80
ILS 3Y	1.31***(0.06)	-0.62***(0.06)	0.92	1.16***(0.10)	-0.84***(0.12)	0.82	1.09***(0.07)	-0.85***(0.07)	0.88
ILS 5Y	0.86***(0.05)	-0.83***(0.08)	0.87	0.77***(0.05)	-0.72***(0.07)	0.86	0.76***(0.05)	-0.79***(0.06)	0.86
ILS 10Y	0.61***(0.03)	-0.96***(0.06)	0.88	0.49***(0.04)	-0.74***(0.04)	0.84	0.54***(0.03)	-0.84***(0.05)	0.85
Real Rates									
OIS Real 1y	-0.33*(0.28)	0.72**(0.28)	0.18	-0.42**(0.21)	0.78***(0.27)	0.17	-0.12(0.22)	1.04***(0.27)	0.17
OIS Real 2y	0.08(0.17)	1.14***(0.24)	0.52	0.01(0.19)	1.31***(0.27)	0.36	0.26*(0.15)	1.37***(0.20)	0.51
OIS Real 3y	0.22(0.19)	1.13***(0.27)	0.45	0.18(0.20)	1.29***(0.31)	0.31	0.39***(0.17)	1.39***(0.23)	0.46
OIS Real 5y	0.55***(0.17)	1.31***(0.31)	0.31	0.45***(0.18)	0.96***(0.29)	0.22	0.60***(0.16)	1.22***(0.23)	0.32
OIS Real 10y	0.28*(0.18)	0.96***(0.37)	0.11	0.29*(0.16)	0.55**(0.31)	0.07	0.37**(0.16)	0.98***(0.28)	0.17
Stock Prices									
Eurostoxx50	0.14***(0.07)	-0.28***(0.08)	0.15	0.13***(0.06)	-0.21***(0.07)	0.13	0.14***(0.06)	-0.21***(0.08)	0.12
Corporate Bonds									
NFC	0.84***(0.15)	0.75***(0.26)	0.31	0.72***(0.14)	0.48***(0.25)	0.25	0.84***(0.14)	0.71***(0.18)	0.35
Banks	0.67***(0.13)	0.93***(0.20)	0.31	0.61***(0.13)	0.71***(0.20)	0.29	0.68***(0.13)	0.86***(0.16)	0.34

Responses of the (daily) variations of financial instruments to Delphic and Odyssean factors. Factors are constructed using the full monetary policy event window, the mere press conference window, and extending the OIS maturity by addding the 3Y OIS rate, and the 5Y and 10Y German Bund yields. Odyssean or Delphic factors are normalized so to generate a 1% increase in the 1 year OIS rate. One, two, and three asterisks indicate statistical significance at 10%, 5%, and 1%, respectively. Robust Standard Error in parenthesis.

Figure D.3: Responses of expectations, prices and output to an Odyssean impulse constructed using the full policy event (left panels) and only the press conference window (central panels) and with an extended maturity structure (right panels). From top left to bottom right EONIA swaps slope (difference between one year and three month OIS rates), log of industrial production and of HICP excluding food and energy. Bands constructed using multi block bootstrap as in Jentsch and Lunsford (2019).

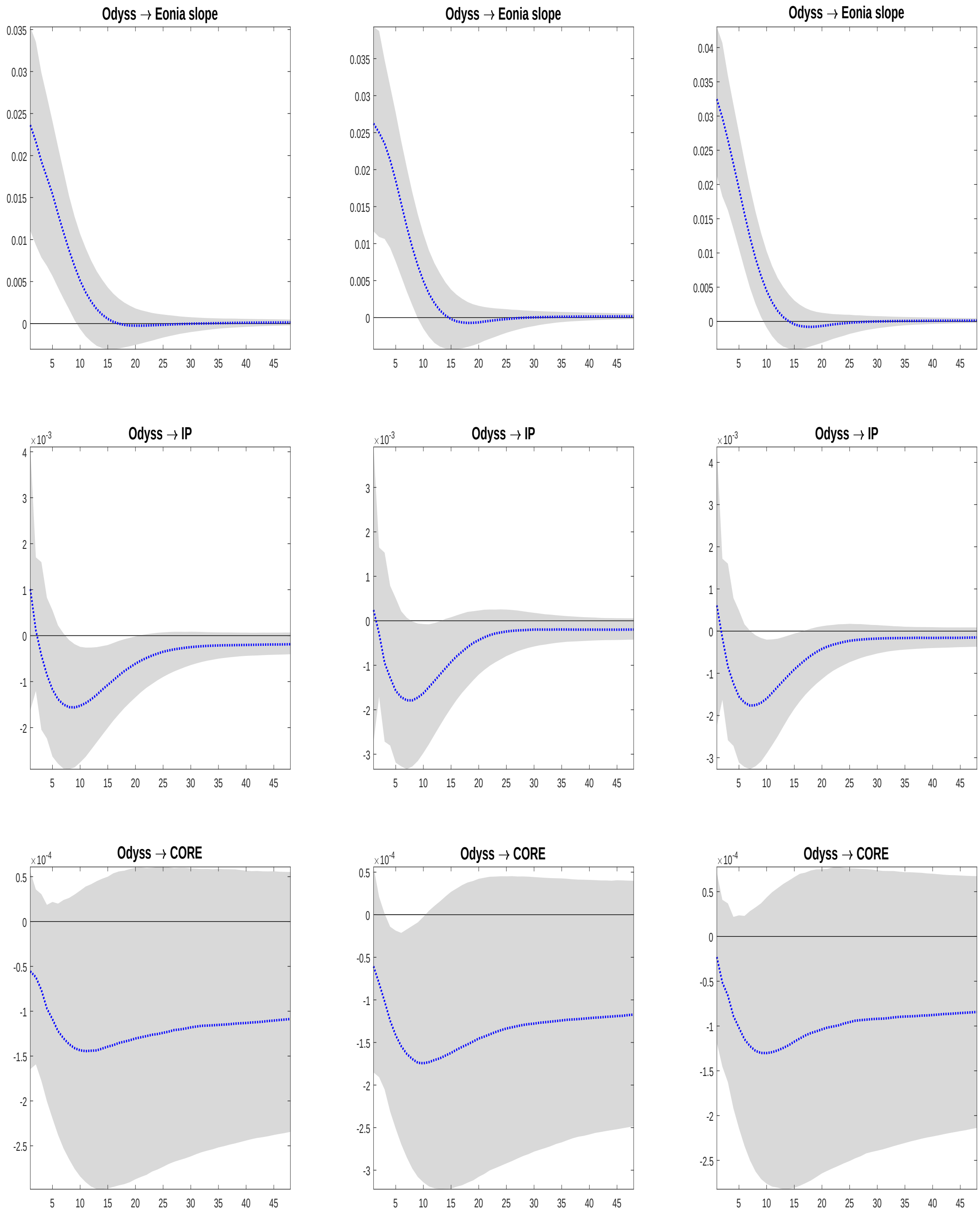
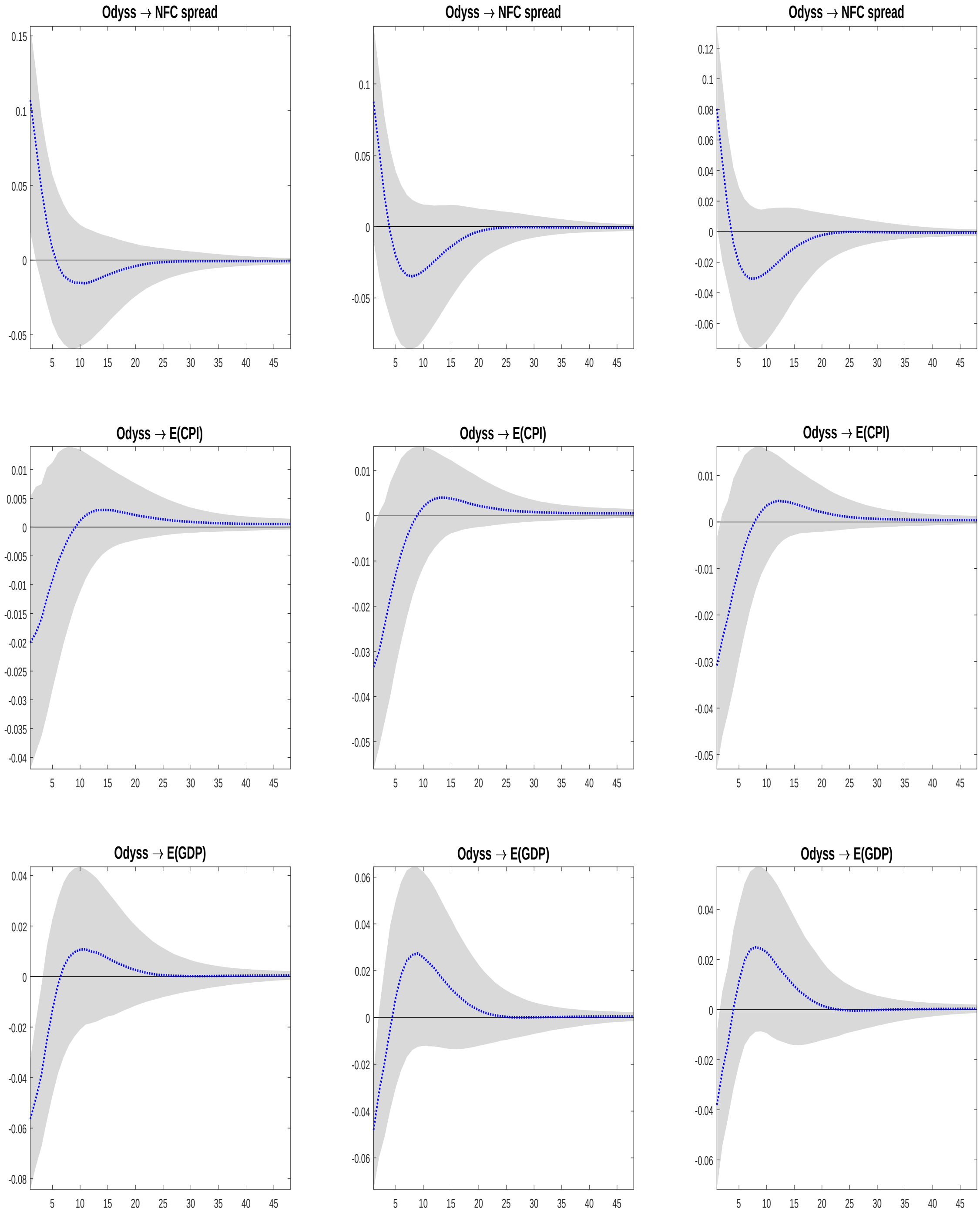


Figure D.4: Responses of expectations, prices and output to an Odyssean impulse constructed using the full policy event (left panels) and only the press conference window (central panels) and with an extended maturity structure (right panels). From top to bottom, non-financial corporation spread, next year expectations about inflation and GDP growth. Bands constructed using multi block bootstrap as in Jentsch and Lunsford (2019).



Appendix E. Impact on macroeconomic expectations: further evidence using a panel of professional forecasters

Table E.6 reports the regressions estimating the monthly variations of GDP and inflation forecasts of individual institutions surveyed by Consensus Economics on the estimated high-frequency surprises, controlling for individual fixed effects. Namely it reports estimates of

$$\Delta E_i = \alpha_i + \beta \text{Target} + \gamma \text{Path} + \varepsilon_i$$
$$\Delta E_i = \alpha_i + \beta \text{Target} + \delta \text{Delphic} + \kappa \text{Odyssean} + \nu_i,$$

where ΔE_i is the change in expectations of either euro-area GDP growth or HICP inflation at the end of the current or next year for individual i in the panel of Consensus Economics. We consider the surveys that are conducted before and after a Governing Council meeting. Fourteen dates for which the monthly revision in the Consensus Forecasts preceded a Governing Council meeting were dropped from our sample, see tables E.7.

The effects of the Delphic and Odyssean shocks on forecast revisions are of the same order as what is obtained when looking at a regression with the median forecasts instead of the individual ones. This is consistent with the nature of these two shocks. A key difference with the regression using the median revision is that the effects are also statistically significant thanks to the larger number of observations we get with individual data.

Table E.6: Central bank communication and macroeconomic expectations

	Target	Path	Adj R^2	Target	Delphic	Odyss.	Adj R^2
Δ GDP growth forecasts							
current calendar year	-0.41***	0.18***	-0.01	-0.41**	0.73***	-0.17	0.01
next calendar year	-1.73***	0.34***	0.04	-1.65***	0.29	-0.52***	0.02
Δ CPI inflation forecasts							
current calendar year	0.35***	-0.16***	-0.01	0.31***	0.13**	-0.48***	-0.01
next calendar year	-0.72***	-0.11**	-0.00	-0.75***	0.17*	-0.51***	0.00

Regression estimating the monthly variation in the Consensus Forecasts individual forecasts on the factors. Fixed effect estimates and statistical significance, 1(5 and 10) % indicated with $***$ ($**$ and $*$) with robust SE.

Table E.7: Monetary Policy and the Consensus Survey date.

Monetary Policy Event	Consensus Economic Survey Collected
2005/1/13	2005/1/10
2006/1/12	2006/1/9
2007/1/11	2007/1/8
2007/4/12	2007/4/10
2009/1/15	2009/1/12
2010/1/14	2010/1/11
2011/1/13	2011/1/10
2011/4/7	2011/4/4
2012/1/12	2012/1/9
2015/1/22	2015/1/12
2015/4/15	2015/4/13
2015/7/16	2015/7/13
2015/10/22	2015/10/12
2016/1/21	2016/1/11

Episodes where the day of monetary policy events occurs after the Survey date.

Appendix F. VAR Robustness

A popular way to measure the dynamic transmission of a macroeconomic shocks is to use VAR models. VAR models assume that the joint comovements of the macroeconomic variables can be described by linear lag structure of order p, which takes the following form:

$$y_t = \Phi_0 + \Phi_1 y_{t-1} + ...\Phi_p y_{t-1} + e_t \quad e_t \sim N(0, \Sigma),$$

where y_t is a vector that contains the observable variables, and ϵ_t is a vector of a normal zero mean identically distributed and serially uncorrelated shocks with $\Sigma = E(\epsilon_t \epsilon_t')$. Note that $\Phi_0, \Phi_1, ..., \Phi_p$ are matrices of appropriate dimensions describing the dynamics of the system. We can rewrite the VAR in a companion form—that is, $y_t = x_t'\Phi + e_t$, where $x_t = [y_{t-1}', ..., y_{t-p}', 1]'$, with Φ being the companion form matrix—and estimate the parameters of interest either with classical estimators or by using a Bayesian approach. Under the assumption of normal distribution of the residuals, the reduced-form VAR is compatible with several structural representations in which reduced-form shocks can be expressed as linear combination of structural uncorrelated innovation; that is,

$$e_t = \Omega \nu_t,$$

where $\Omega\Omega' = \Sigma$, $E(\nu_t \nu_t') = I_n$. Since it is likely the data are flat along the Ω matrix dimension, additional restrictions are needed to identify the structural shocks.

Following Mertens and Ravn (2013) and Stock and Watson (2012), we map the reduced-form VAR residuals with the structural shock of interest by *instrumenting* the VAR residuals (observable) with a measurable proxy for the structural shock (unobservable). In our context, the proxy for monetary policy shocks is given by either the Path factor or the Odyssean shocks extracted from the high-frequency data as discussed in previous sections. This approach allows us to recover the first column of the rotation matrix Ω and thus to recover impulse responses and the transmission mechanism. More formally, let m_t be the time series proxy for the unobserved structural shock. Assume, without loss of generality, that the proxy is linked to the first shock as follows

$$\begin{aligned} E(\nu_t m_t) &= [\rho, 0, ..., 0]', \\ E(\Omega \nu_t m_t) &= \Omega[\rho, 0, ..., 0]', \\ E(e_t m_t) &= \rho[\Omega_{11}, \Omega_{2:N,1}']'. \end{aligned}$$

Assuming that the first reduced-form shock is related to the observed proxy, we can partition the two sets of relationships and obtain

$$E(e_{2,t} m_t) E(e_{1,t} m_t)^{-1} = \Omega_{11}^{-1} \Omega_{2:N,1},$$

where the second equation can be estimated using the sample analog, since m_t is observable, e_t is observable conditional on Φ and Σ, and they are both stationary. This restriction, coupled with the fact that $\Omega\Omega' = \Sigma$, gives rise to a set of equations that, up to a sign normalization, uniquely pin down the first column of the rotation matrix.

The econometric approach works as follows. We first run the VAR ordinary least square (OLS) regression to obtain Φ and Σ. We next isolate the variation in the reduced-form residual of the policy indicator that is attributable to the proxy. We then regress the remaining reduced-form residuals on the fitted value of the first regression. To obtain the confidence bands around the impulse response, we follow Jentsch and Lunsford (2019) and run a multi-block bootstrap of the VAR residuals. We also constructed Bayesian confidence sets using uninformative priors on the VAR parameters along the lines discussed in Miranda-Agrippino and Ricco (Forthcoming) (see figures F.5 and F.6). With Bayesian inference the propagation of shock seems more persistent. However, the qualitative pattern is similar across inferential approaches.

Most of the exercises presented in this section are performed using the empirical macro toolbox described in Ferroni and Canova (2020).

The baseline VAR specification includes six variables: the difference between the one-year and the three-month EONIA swap rates, which is a measure of the slope of the term structure of rates; the seasonally adjusted (log) industrial production index (excluding construction); the (log) HICP excluding energy and food prices; and the Gilchrist and Mojon (2017) credit spread. We also include survey measures of expectations, namely the Consensus Forecasts for next year's GDP growth and next year's inflation rate. The IRFs are displayed in figure 3. Substituting the Consensus Forecasts for next year's GDP growth and next year's inflation rate with their fixed horizon counterparts does not change the results, see figures F.7- F.8.

We also considered an alternative VAR specification consisting of the slope EONIA 1y- 3m swap rates, the seasonally adjusted (log) industrial production index (excluding construction); the (log) HICP and the (log) HICP excluding energy and food prices; and the Gilchrist and Mojon (2017) credit spread; the 5y ILS and the 3M EONIA swap rate. Figures F.9 and F.10 report the responses of the endogenous variables to an impulse in the Path and Odyssean factors respectively. This VAR specification provides broadly the same results as in the benchmark case. A finding that might look puzzling at first glance in this specification is that the short-term interest rate declines after an Odyssean tightening. However, this is consistent with a Fischer effect and lower expected inflation.

Our preferred modeling strategy to study the dynamic transmission of exogenous policy variations to the macroeconomic aggregates is the Vector Autoregressive (VAR) model. An alternative modeling strategy to derive the dynamic transmission of monetary policy shocks is to use local projections (LP). While asymptotically VAR and LP estimate the same impulse response function *up to a scaling factor* (see Plagborg-Moller and Wolf (2019)), in small samples we face a bias-variance trade off, an analogous situation to the choice between 'direct' and 'iterated' predictions in a multi-step forecasting exercise. The forecasting literature has generally found that LP (direct) methods tend to have relatively low bias, whereas VAR (iterated) methods have relatively low variance; and the trade-off is most relevant at longer horizons. In our case, we opted for the VAR to enhance the precision of the IRF estimates and treated the LP results as a robustness exercise to verify the consistency of the sign of the responses across the two methods. Figures F.11 and F.12 report the IRF using LP methods where we used as controls the two lags of the variable of interest and two lags of industrial production, interest rate and core inflation. While the uncertainty around the LP IRF is typically larger, the sign patterns are consistent with the VAR IRFs.

Figure F.5: Responses of expectations, prices and output to an impulse in the Odyssean (right panels) and path factor (left panels). From top to bottom EONIA swaps slope (difference between one year and three month OIS rates), log of industrial production and of HICP excluding food and energy. The gray bands 68% confidence sets; Bayesian confidence sets constructed as in Miranda-Agrippino and Ricco (2019) with uninformative priors on the reduced form parameters..

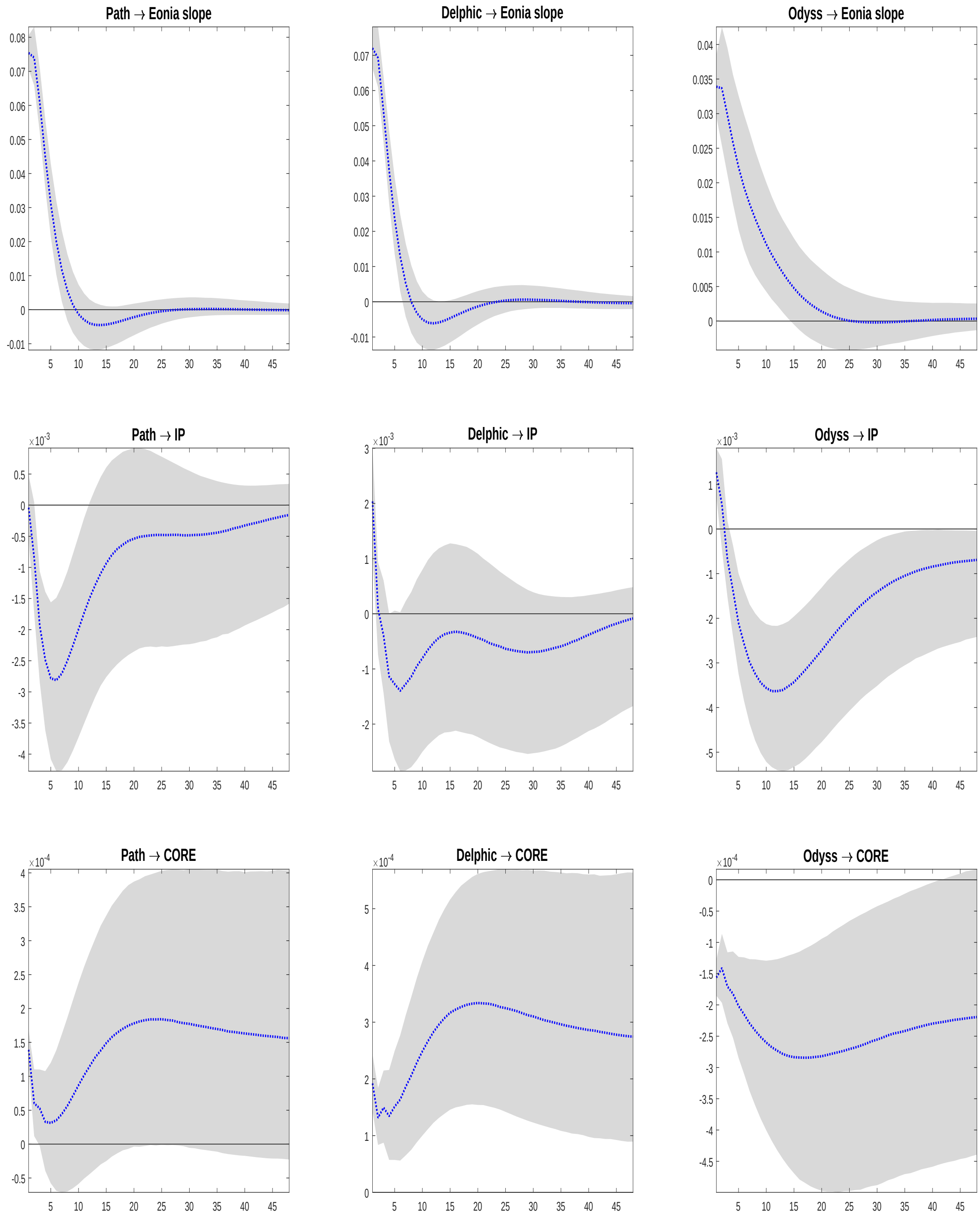


Figure F.6: Responses of expectations, prices and output to an impulse in the Odyssean (right panels) and path factor (left panels). From top to bottom non-financial corporation spread, next year expectations about inflation and GDP growth.The gray bands 68% confidence sets; Bayesian confidence sets constructed as in Miranda-Agrippino and Ricco (2019) with uninformative priors on the reduced form parameters.

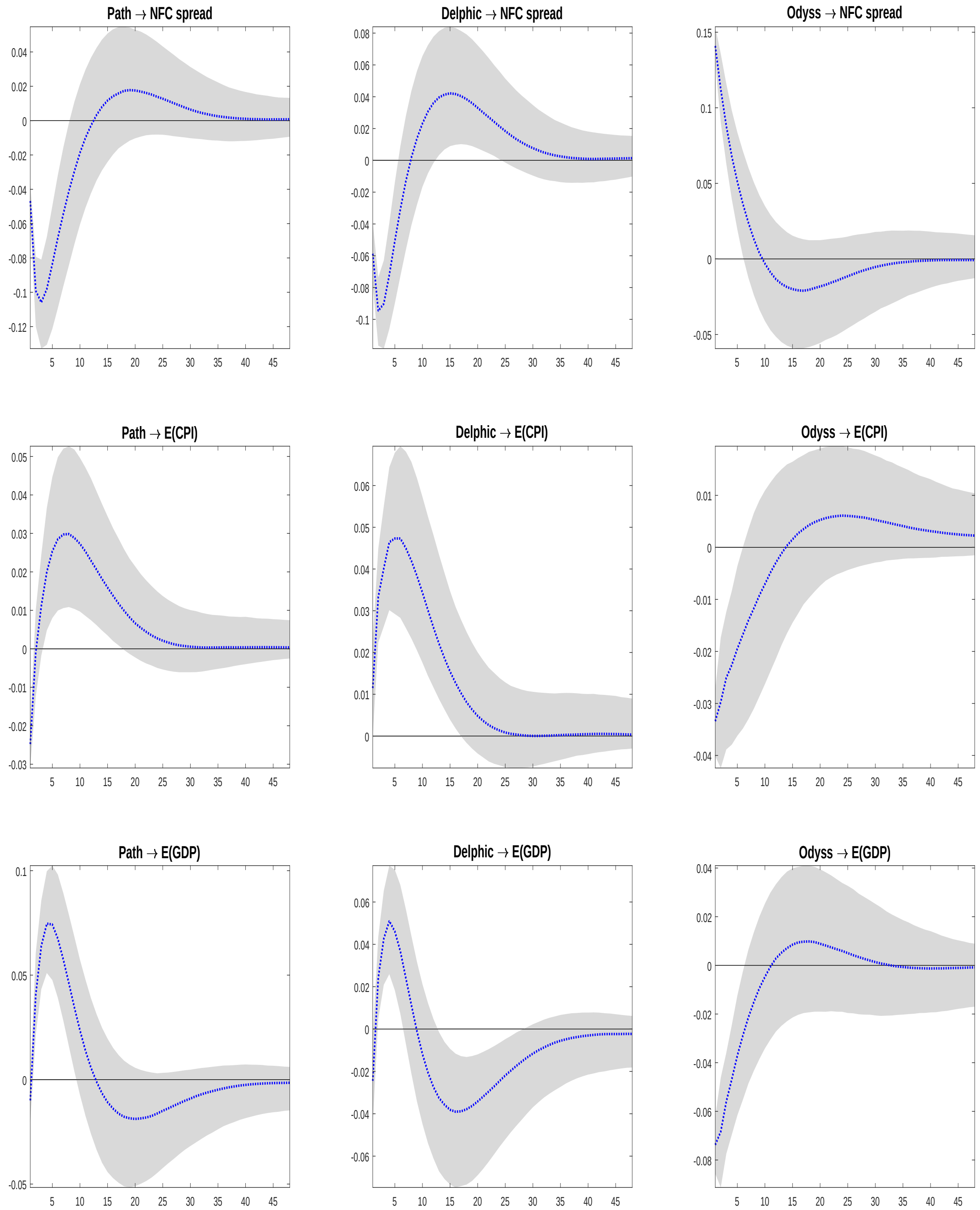


Figure F.7: Responses of expectations, prices and output to an to an impulse in the path factor (left panels) and Odyssean factor (right panels). From top to bottom, EONIA swaps slope (difference between one year and three month OIS rates), log of industrial production and of HICP. Bands constructed using multi block bootstrap as in Jentsch and Lunsford (2019).

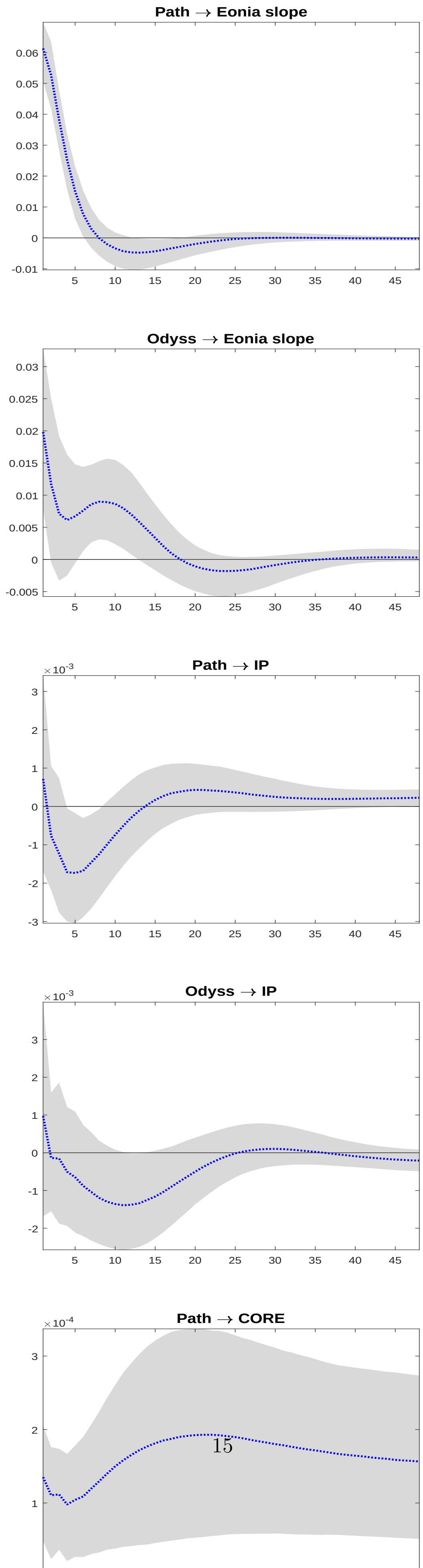


Figure F.8: Responses of expectations, prices and output to to an impulse in the path factor (left panels) and Odyssean factor (right panels). From top to bottom, NFC spread and fixed horizon consensus forecasts for output and inflation. Bands constructed using multi block bootstrap as in Jentsch and Lunsford (2019).

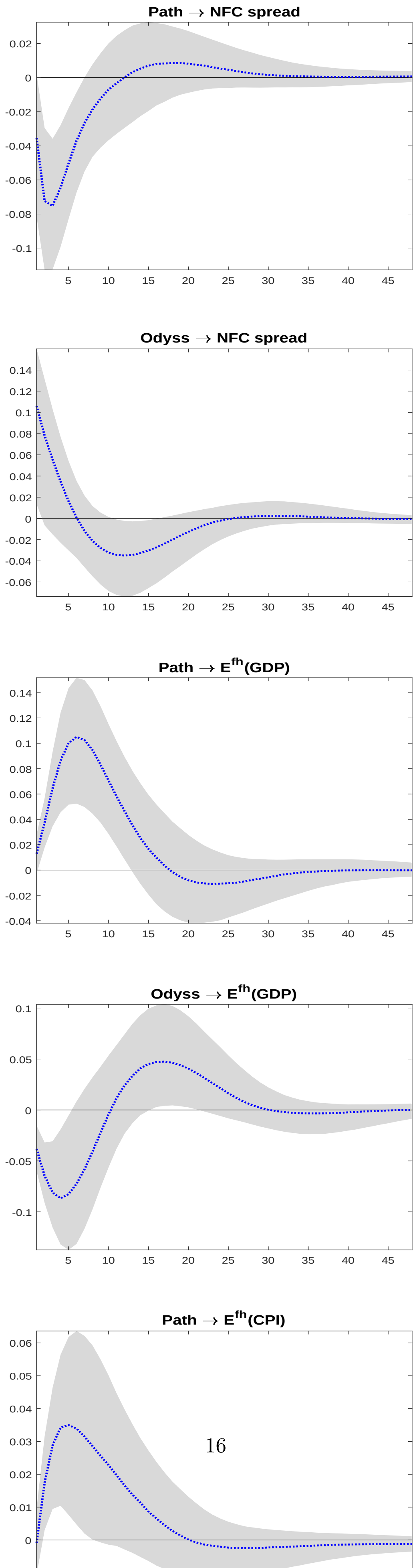


Figure F.9: Responses of expectations, prices and output to an impulse in the path factor (left panels) and Odyssean factor (right panels). From top to bottom, EONIA swaps slope (difference between one year and three month OIS rates), log of industrial production and of HICP. Bands constructed using multi block bootstrap as in Jentsch and Lunsford (2019).

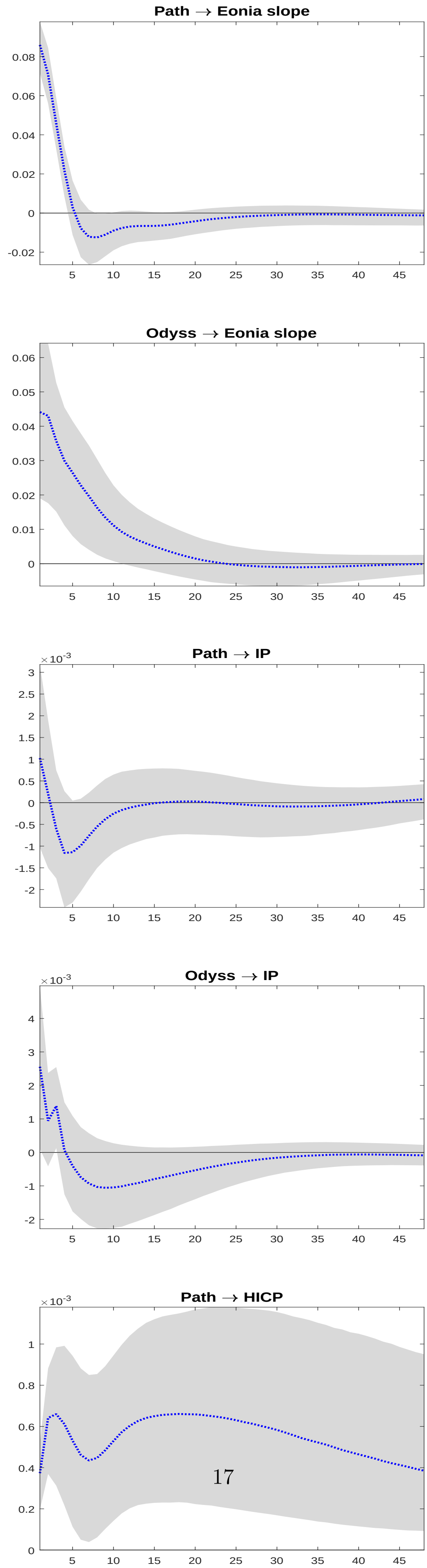


Figure F.10: Responses of expectations, prices and output to an impulse in the path factor (left panels) and Odyssean factor (right panels). From top to bottom, credit spread, 3M OIS and 5Y ILS. Bands constructed using multi block bootstrap as in Jentsch and Lunsford (2019).

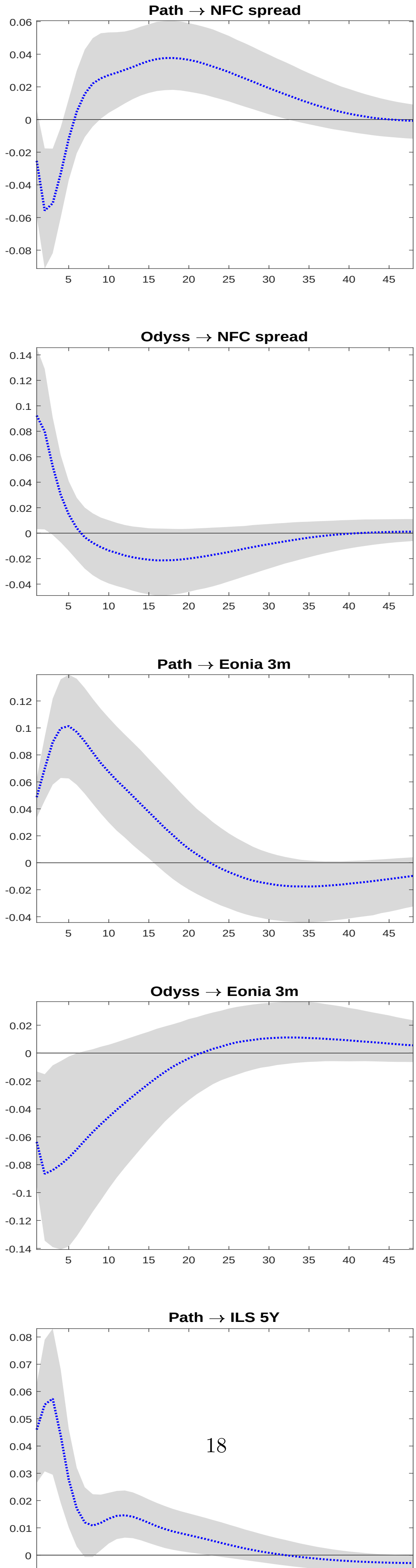


Figure F.11: Responses of prices and output to an impulse in the path factor (left panels) and Odyssean factor (right panels) using linear projection techniques. From top to bottom, EONIA swaps slope (difference between one year and three month OIS rates), year-on-year industrial production growth and Core and HICP year-on-year inflation.

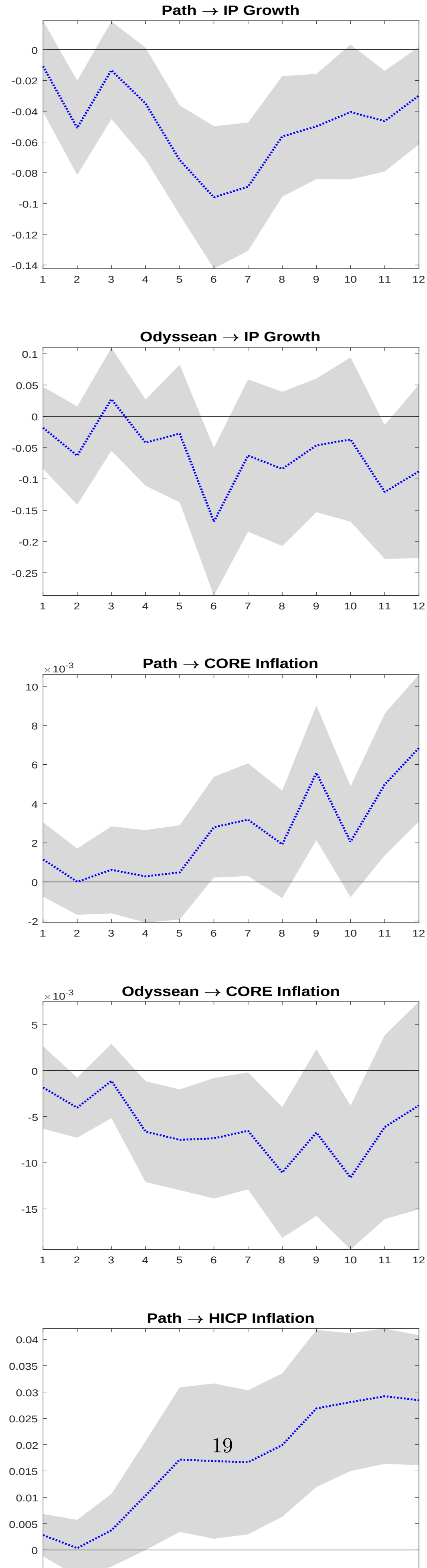
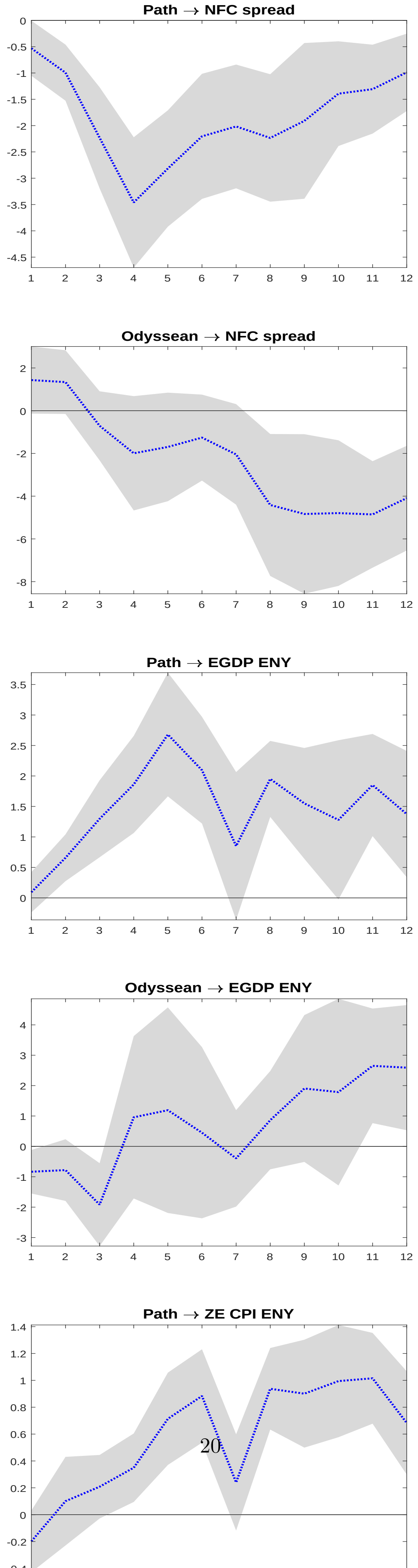


Figure F.12: Responses of prices and output to an impulse in the path factor (left panels) and Odyssean factor (right panels) using linear projection techniques. From top to bottom, NFC spread and next year forecasts of output growth and inflation.



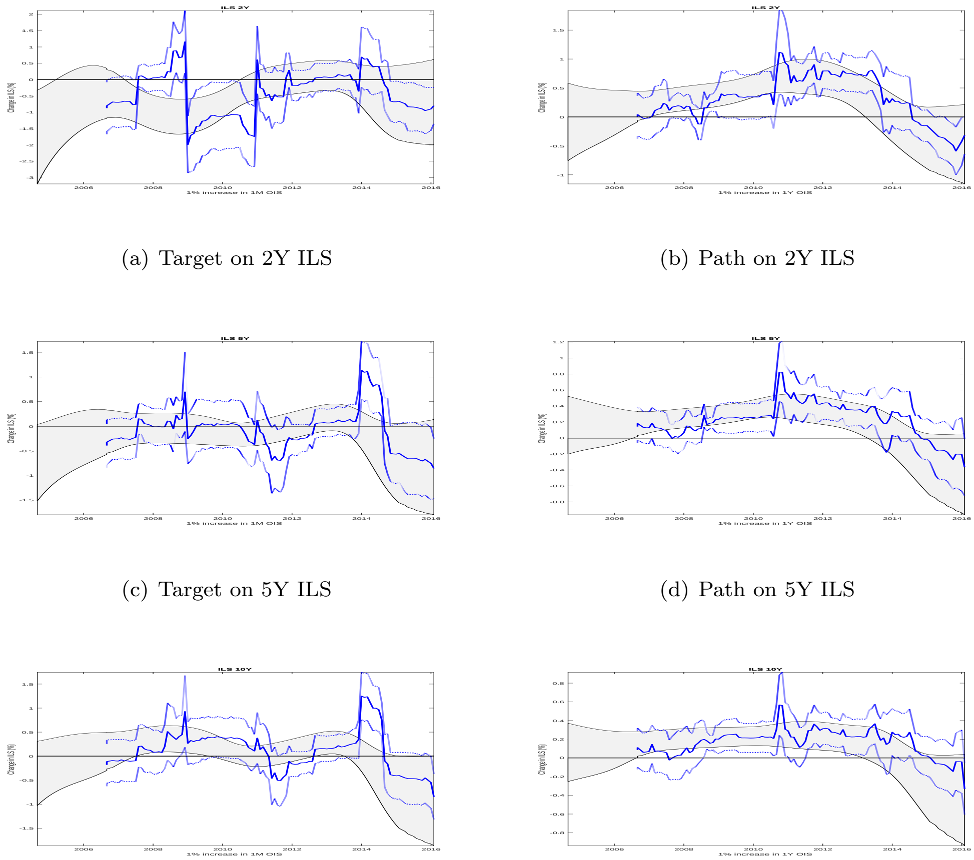
Appendix G. Time variation in the response of ILS to the Path factor

To gauge more evidence on the possible time variation in the impact of the Target and Path factors on inflation expectations, we conduct two complementary exercises where we do not arbitrarily select the subsamples. The first exercise is based on a rolling window regression and the second on a local kernel regression, which has the advantage of smoothing the abrupt time variation of the rolling window estimates. The local kernel regression is a form of rolling regression with a different data-weighting scheme. More formally, for each $\tau = 1, .., T$, we minimize the following residual sum squares:

$$\sum_{t=1}^{T} K_f\left(\frac{t-\tau}{h}\right)(ILS_{j,t} - \eta_t' B_\tau),$$

where $K_f(.)$ is the Gaussian kernel function and h is the bandwidths, and where η_t collects the Path and Target factors (and a constant). Data points far from τ will have small weights, yet are nonzero as in the rolling window.Figure G.13 reports the rolling sample estimates of the impact of the Target factor (left panels) and Path factor (right panels) on market-based inflation expectations. In particular, the blue solid and dashed lines plot the OLS estimates of regressing the financial instrument on the Target factor and the Path factor along with the 90% confidence bands in a 24-month window. The gray areas report the same information using a local linear kernel estimator. The impact of the Target factor tends to be relatively stable over the rolling windows, fluctuating between negative or nonsignificant values. The impact of the Path factor instead displays slowly moving time variation, switching from positive to negative values.While in the central part of our sample the ECB communication had a Delphic component, the last part of the sample is dominated by the Odyssean forward guidance.

Figure G.13: Impact of the Path factor on the ILS over rolling windows or with a local kernel estimator



(a) Target on 2Y ILS

(b) Path on 2Y ILS

(c) Target on 5Y ILS

(d) Path on 5Y ILS

(e) Target on 10Y ILS

(f) Path on 10Y ILS

Appendix H. Predictability of euro-area monetary policy surprises

In this section, we detail the exercises we run to test the predictability of our measures of monetary policy surprises. First, monetary policy surprises extracted from high frequency data appear to be independent across time, see H.14. Moreover, we tested if they are orthogonal to the information available to market participants before the monetary policy event. One simple way to test the predictability is to project the Path and Target factors onto a rich set of variables intended to capture the information set common to the central bank and the agents. More precisely, let F_t be the vector containing the Target and Path factors at time t, and let X_t be a vector collecting a number of macroeconomic and financial variables. We define the following system:

$$X_t = \Lambda \mathbf{f}_t + u_t,$$
$$F_{t+1} = \mathbf{f}_t' B + e_{t+1},$$

where $\mathbf{f}_t$ are some factors summarizing the information content of X_t, the set of observables whose realizations are known before the announcement; e_t and u_t are independent identically distributed (i.i.d.) shocks; and B is the matrix that loads the factors onto the monetary policy surprises. If B is statistically significant, then monetary policy surprises can be predicted by using past common information.

We include a total of about 40 variables in X_t that are related to macro data, financial variables, and surveys. More details on selection and transformation of variables are reported in table H.11. The test is run in various steps. We first extract the first principal component, which explains about 70 percent of the volatility of the entire data set. Factors are extracted on a rolling basis in order to avoid including the information available after the announcement. In a second step, we regress either the Path or the Target factor on the lagged macro factors and look at the F and t statistics to test for statistical significance.

Table H.8 reports the individual p-values of the coefficients of the regression of the Path and Target factors on lagged macroeconomic, financial, and surveys factors or only lagged financial factors. The last row reports the F-test of the joint statistical significance. Overall, the publicly available information seems to explain very little of the interest rate variations in a narrow window around the monetary policy press conference. If anything, one macro factor appears to be statistically influential in explaining the Target factor. Factor #5 can be associated with measures of inflation. Table H.9 reports the regression estimating f_5 on each observable variable in the factor model, $f_{5,t} = \alpha_0 + \alpha_0 X_{j,t} + e_t$. Individual regressions are ranked with respect to the R^2. Core and headline HICP inflation explain one-fourth of the variation in the $f_{5,t}$. However, monetary policy announcements about future monetary policy actions (Path factor) are not predictable using past information.

We also test whether the central bank has private infromation relative to the private sector that it reveals when it releases its staff forecasts. The main text reports the results of regressions similar to Miranda-Agrippino and Ricco (Forthcoming):

$$\text{Factor} = \alpha + \theta' \text{PR}^{\text{ECB}} + \omega,$$

where $\text{Factor} = \{\text{Target}, \text{Path}, \text{Odyssean}, \text{Delphic}\}$, and PR^{ECB} is a vector that contains ECB staff projections of GDP growth and CPI inflation for the current and next calendar years or their revisions compared with the previous quarter.

In this Appendix, we also implement an approach similar to Campbell, Fisher, Justiniano and Melosi (2017). They use the difference between the Blue Chip forecasts and the Greenbook forecasts as an observable proxy for information asymmetry. They interpret this difference as the amount of Delphic forward guidance contained in the monetary policy announcements. We construct an observable proxy for the informartion asymmetry in the euro area. We consider inflation and real GDP forecasts obtained from the Survey of Professional Forecasters as a measure of private-sector forecasts and from the Eurosystem staff projections for the euro area as a measure of central bank forecasts. Tables H.12 and H.13 report the available figures at quarterly frequency.[1] The regression results are poor. The R^2 results are low, and either singularly or jointly we fail to reject the singularity of coefficients. And even for $k = 0$, the Path factor is not explained by the discrepancy between central bank and private sector forecasts.

Overall, we do not think that there is enough evidence to conclude that the Path, the Odyssean, or the Delphic factor responds to Eurosystem forecasts and forecast revisions.

[1] Data can be downloaded from the ECB webpage.

Figure H.14: Autocorrelation and partial autocorrelation function for the Path and the Target factors. Blue bands indicate statistical significance.

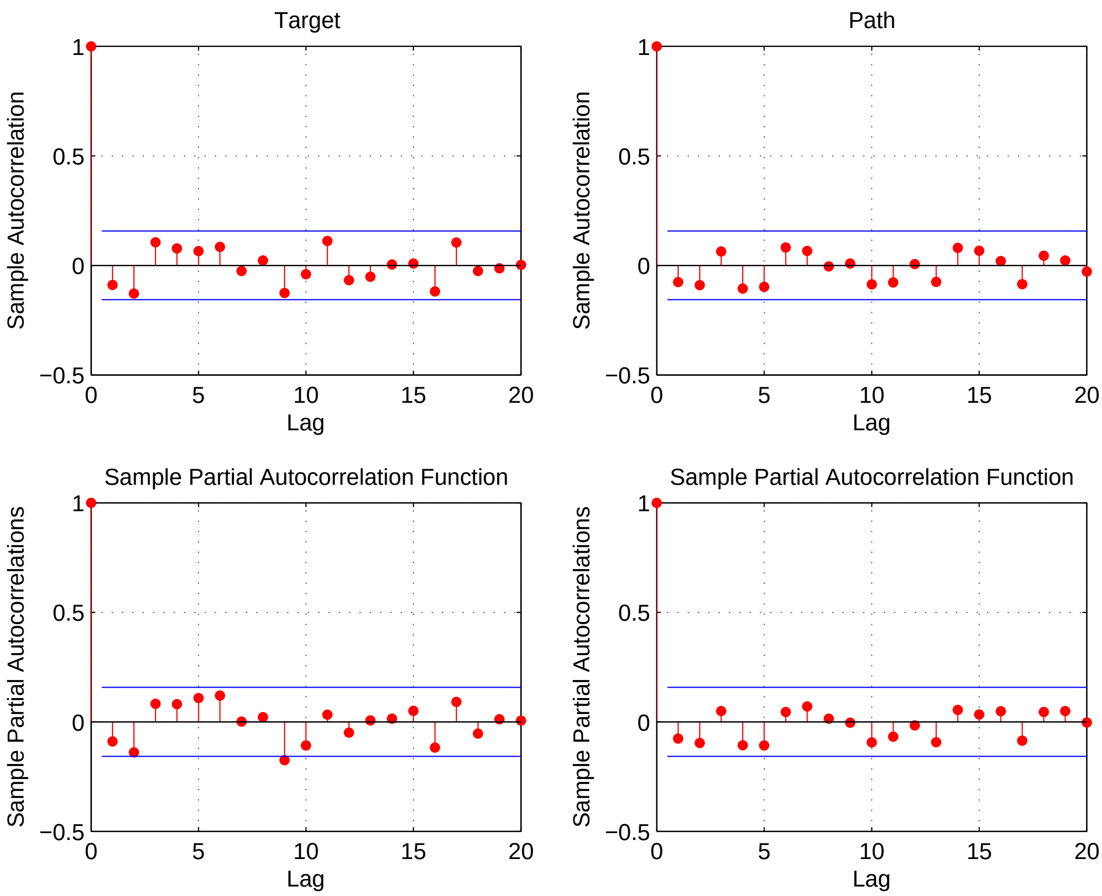


Table H.8: Predictability of HF monetary policy surprises.

Factors in set of 40 variables	Target	Path
const	0.25	0.39
f_1	0.22	0.32
f_2	0.35	0.19
f_3	0.18	0.35
f_4	0.22	0.37
f_5	0.05	0.38
f_6	0.22	0.38
f_7	0.25	0.25
F test	1.52	0.49

P-values of the regression of the Path and Target factors on macroeconomic and financial lagged factors. Last row reports the F statistics.

Table H.9: Regression Estimating f_5 on each observable variables in the factor model.

	R^2	OLS Coeff
CORE	0.24	1.63*** (0.24)
HICP	0.22	1.77*** (0.31)
UNRATE	0.03	3.36** (1.35)
TURNOVERRET	0.03	0.02* (0.01)
CCI	0.03	-0.17** (0.07)
UNRATEPER	0.03	0.23** (0.10)
BRENT	0.02	0.03 (0.02)
UKEUROSPOT	0.02	12.50* (7.22)
DJ50	0.02	-0.05** (0.02)
ESI	0.02	-0.13** (0.06)
SP500	0.02	-0.05** (0.02)
IPIEN	0.02	-0.03* (0.02)
CE16OV	0.02	-0.80 (0.57)
UNRATEUS	0.01	1.07* (0.62)
IPINOCOSTREN	0.01	-0.13 (0.09)
3MEURIBOR	0.01	-1.00 (0.73)
LOANS	0.01	-0.36 (0.24)
IPINOCOSTR	0.01	-0.14 (0.10)
TURNOVERMAN	0.01	0.01 (0.01)
M3	0.01	-0.25 (0.27)
IPIINTER	0.01	-0.01 (0.01)
NEWORDER	0.00	-0.04 (0.05)
YENEUROSPOT	0.00	0.02 (0.03)
GS10	0.00	0.41 (0.59)
1YEURIBOR	0.00	-0.49 (0.78)
IPITOT	0.00	0.01 (0.01)
EONIA	0.00	-0.39 (0.82)
RRSFS	0.00	-0.06 (0.09)
TB3MS	0.00	-0.27 (0.54)
IPIDUR	0.00	0.00 (0.00)
CARREG	0.00	0.00 (0.01)
PCOMM	0.00	-0.01 (0.03)
REXRATE	0.00	-0.01 (0.08)
NAPM	0.00	-0.00 (0.03)
CPIUS	0.00	0.02 (0.38)
IPICONS	0.00	0.00 (0.01)
DOLEUROSPOT	0.00	0.11 (3.64)

Regression estimating f_5 on each observable variable in the factor model; that is, $f_{5,t} = \alpha_0 + \alpha_0 X_{j,t} + e_t$. OLS estimates and statistical significance, 1(5 and 10) % indicated with $***$ ($**$ and $*$) with robust SE.

Table H.10: Monetary policy surprises and information gaps

	Const	HICP	HICP(+1)	RGDP	RGDP(+1)	F test	R2
Lagged ($k = 1$)							
Target	0.38	0.40	0.38	0.36	0.27	0.70	0.05
Path	0.20	0.39	0.31	0.39	0.40	0.22	0.02
Contemporaneous ($k = 0$)							
Target	0.37	0.03	0.04	0.19	0.32	2.29	0.15
Path	0.06	0.37	0.35	0.28	0.19	0.57	0.04

Information gaps are derived by taking the difference between the SFP and the ECB current or next year forecasts of real GDP and HICP.

Table H.11: List of variables included in X_t to test the predictability of monetary policy surprises. Transformations: 1 = first difference, 2 = growth rate

Variables	Transf
ECB Nominal effective exch. Rate	1
UK pound sterling/Euro, 2:15 pm (C.E.T.)	1
Japanese yen/Euro, 2:15 pm (C.E.T.)	1
US dollar/Euro, 2:15 pm (C.E.T.)	1
Total Turnover Index, Manifacturing	2
ECB Commodity Price index Euro denominated	2
Standardised unemployment, Rate,	1
Car registration, New passenger car;	2
Total Turnover Index, Retail trade including fuel	2
New orders, total, MANUFACTURING, FOR NEW ORDERS	2
Industrial Production Index, Total Industry (excluding construction)	2
Industrial Production Index, Total Industry excluding construction and MIG Energy	2
Brent crude oil 1-month Forward	2
Equity index - Dow Jones Eurostoxx 50 index - Index	2
Rate - Eonia rate - Euro	1
Rate - 1-year Euribor (Euro interbank offered rate) - Euro	1
Rate - 3-month Euribor (Euro interbank offered rate) - Euro	1
Equity index - Standard and Poor 500 - Index	2
Exchange rate, ECB real effective exchange rate CPI deflated	2
Loans, total maturity, all currencies combined	2
Monetary aggregate M3, all currencies combined	2
HICP - Overall index - Index	2
HICP - All-items excluding energy and unprocessed food - Index	2
Standardised unemployment, Total (all ages), Male - Percentage	1
Consumer Survey - Consumer Confidence Indicator - Percentage	2
Economic Sentiment Indicator - Percentage	2
Industrial Production Index, Consumer goods industry - Index	2
Industrial Production Index, MIG Durable Consumer Goods Industry - Index	2
Industrial Production Index, MIG Energy - Index	2
Industrial Production Index, Total Industry - Index	2
Industrial Production Index, MIG Intermediate Goods Industry - Index	2
United States - CONSUMER PRICES, ALL ITEMS	2
United States - Employment	1
United States - 10-Year Treasury Constant Maturity Rate	1
United States - Manufacturing ISM Report on Business	2
United States - Real Retail and Food Services Sales	2
United States - Three months treasury bill	1
United States - Unemployment rate	1

Table H.12: Eurosystem staff projections for the euro area, inflation and real GDP.

	HICP		Real GDP	
	Current Y	Next Y	Current Y	Next Y
March 2002	1.8	1.6	1.0	2.5
June 2002	2.3	1.9	1.2	2.6
September 2002	2.2	1.8	0.8	2.1
December 2002	2.2	1.8	0.8	1.6
March 2003	2.0	1.5	1.0	2.0
June 2003	2.0	1.3	0.7	1.6
September 2003	2.1	1.5	0.4	1.5
December 2003	2.1	1.8	0.4	1.6
March 2004	1.7	1.5	1.5	2.4
June 2004	2.1	1.7	1.7	2.2
September 2004	0.2	1.3	1.6	1.7
December 2004	2.2	2.0	1.8	1.9
March 2005	1.9	1.6	1.6	2.1
June 2005	2.0	1.5	1.4	2.0
September 2005	2.2	1.9	1.3	1.8
December 2005	2.2	2.1	1.4	1.9
March 2006	2.2	2.2	2.1	2.0
June 2006	2.3	2.2	2.1	1.8
September 2006	2.4	2.4	2.5	2.1
December 2006	2.2	2.0	2.7	2.2
March 2007	1.8	2.0	2.5	2.4
June 2007	2.0	2.0	2.6	2.3
September 2007	2.0	2.0	2.5	2.3
December 2007	2.1	2.5	2.6	2.0
March 2008	2.9	2.1	1.7	1.8
June 2008	3.4	2.4	1.8	1.5
September 2008	3.5	2.6	1.4	1.2
December 2008	3.3	1.4	1.0	-0.5
March 2009	0.4	1.0	-2.7	0.0
June 2009	0.3	1.0	-4.6	-0.3
September 2009	0.4	1.2	-4.1	0.2
December 2009	0.3	1.3	-4.0	0.8
March 2010	1.2	1.5	0.8	1.5
June 2010	1.5	1.6	1.0	1.2
September 2010	1.6	1.7	1.6	1.4
December 2010	1.6	1.8	1.7	1.4
March 2011	2.3	1.7	1.7	1.8
June 2011	2.6	1.7	1.9	1.7
September 2011	2.6	1.7	1.6	1.3
December 2011	2.7	2.0	1.6	0.3
March 2012	2.4	1.6	-0.1	1.1
June 2012	2.4	1.6	-0.1	1.0
September 2012	2.5	1.9	-0.4	0.5
December 2012	2.5	1.6	-0.5	-0.3
March 2013	1.6	1.3	-0.5	1.0
June 2013	1.4	1.3	-0.6	1.1
September 2013	1.5	1.3	-0.4	1.0
December 2013	1.4	1.1	-0.4	1.1
March 2014	1.0	1.3	1.2	1.5
June 2014	0.7	1.1	1.0	1.7
September 2014	0.6	1.1	0.9	1.6
December 2014	0.5	0.7	0.8	1.0
March 2015	0.0	1.5	1.5	1.9
June 2015	0.3	1.5	1.5	1.9
September 2015	0.1	1.1	1.4	1.7
December 2015	0.1	1.0	1.5	1.7
March 2016	0.1	1.3	1.4	1.7
June 2016	0.2	1.3	1.6	1.7

Table H.13: SPF projections for the euro area, inflation and real GDP.

	HICP		Real GDP	
	Current Y	Next Y	Current Y	Next Y
2002 Q1	1.7	1.8	1.3	2.6
2002 Q2	2.1	1.9	1.4	2.7
2002 Q3	2.1	1.8	1.2	2.5
2002 Q4	2.2	1.8	0.8	1.8
2003 Q1	1.8	1.8	1.4	2.3
2003 Q2	2.0	1.7	1.0	2.1
2003 Q3	1.9	1.5	0.7	1.7
2003 Q4	2.0	1.6	0.5	1.7
2004 Q1	1.8	1.7	1.8	2.2
2004 Q2	1.8	1.8	1.6	2.1
2004 Q3	2.1	1.9	1.8	2.1
2004 Q4	2.1	1.9	1.9	2.0
2005 Q1	1.9	1.8	1.8	2.1
2005 Q2	1.9	1.8	1.6	2.0
2005 Q3	2.1	1.8	1.4	1.8
2005 Q4	2.2	2.0	1.3	1.7
2006 Q1	2.0	2.0	2.0	1.9
2006 Q2	2.1	2.1	2.1	1.9
2006 Q3	2.3	2.1	2.2	1.8
2006 Q4	2.2	2.1	2.6	2.0
2007 Q1	2.0	1.9	2.1	2.1
2007 Q2	1.9	1.9	2.5	2.3
2007 Q3	2.0	2.0	2.7	2.3
2007 Q4	2.0	2.0	2.6	2.1
2008 Q1	2.5	2.0	1.8	2.0
2008 Q2	3.0	2.2	1.6	1.6
2008 Q3	3.6	2.6	1.6	1.3
2008 Q4	3.4	2.2	1.2	0.3
2009 Q1	0.9	1.6	-1.0	0.6
2009 Q2	0.5	1.3	-3.0	0.2
2009 Q3	0.4	1.1	-4.0	0.3
2009 Q4	0.3	1.2	-3.0	1.0
2010 Q1	1.3	1.5	1.2	1.6
2010 Q2	1.4	1.5	1.1	1.5
2010 Q3	1.4	1.5	1.1	1.4
2010 Q4	1.5	1.5	1.6	1.5
2011 Q1	1.9	1.8	1.6	1.7
2011 Q2	2.5	1.9	1.7	1.7
2011 Q3	2.6	2.0	1.9	1.6
2011 Q4	2.6	1.8	1.6	0.8
2012 Q1	1.9	1.7	-0.0	1.1
2012 Q2	2.3	1.8	-0.0	1.0
2012 Q3	2.3	1.7	-0.0	0.6
2012 Q4	2.5	1.9	-0.0	0.3
2013 Q1	1.8	1.8	-0.0	1.1
2013 Q2	1.7	1.6	-0.0	1.0
2013 Q3	1.5	1.5	-0.0	0.9
2013 Q4	1.4	1.5	-0.0	1.0
2014 Q1	1.1	1.4	1.0	1.5
2014 Q2	0.9	1.3	1.1	1.5
2014 Q3	0.7	1.2	1.0	1.5
2014 Q4	0.5	1.0	0.8	1.2
2015 Q1	0.3	1.1	1.1	1.5
2015 Q2	0.1	1.2	1.4	1.7
2015 Q3	0.2	1.3	1.4	1.8
2015 Q4	0.1	1.0	1.5	1.7
2016 Q1	0.7	1.4	1.7	1.8
2016 Q2	0.3	1.3	1.5	1.6

References

Altavilla, C., Brugnolini, L., Gürkaynak, R.S., Motto, R., Ragusa, G., 2019. Measuring Euro Area Monetary Policy. Journal of Monetary Economics 108, 162–179.

Campbell, J.R., Fisher, J.D., Justiniano, A., Melosi, L., 2017. Forward Guidance and Macroeconomic Outcomes Since the Financial Crisis. NBER Macroeconomics Annual 31, 283–357.

Cragg, J.G., Donald, S.G., 1997. Inferring the rank of a matrix. Journal of Econometrics 76, 223–250.

Ferroni, F., Canova, F., 2020. A hitchhiker guide to empirical macro models. Working Paper. MIMEO. URL: `https://github.com/naffe15/BVAR_`.

Gilchrist, S., Mojon, B., 2017. Credit Risk in the Euro Area. Economic Journal 128, 118–158.

Jentsch, C., Lunsford, K.G., 2019. The dynamic effects of personal and corporate income tax changes in the united states: Comment. American Economic Review 109, 2655–78.

Mertens, K., Ravn, M.O., 2013. The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States. American Economic Review 103, 1212–47.

Miranda-Agrippino, S., Ricco, G., Forthcoming. The Transmission of Monetary Policy Shocks. American Economic Journal: Macroeconomics .

Plagborg-Moller, M., Wolf, C.K., 2019. Local Projections and VARs Estimate the Same Impulse Responses. Working Paper. Princeton University OpenScholar.

Stock, J.H., Watson, M.W., 2012. Disentangling the Channels of the 2007-09 Recession. Brookings Papers on Economic Activity , 81–156.